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ABSTRACT

The relationship between cognitive development and problem-solving skills is discussed. One approach for improving students' problem-solving skills rests in the application of cognitive development theories to instruction. Instructional strategies that facilitate cognitive development can be categorized into two groups: instruction that challenges the student's cognitive structures or creates disequilibrium, and instruction that provides support such that the student will engage in the opportunity created by the disequilibrium. Four types of instructional strategies that have been used successfully to introduce disequilibrium are considered: creating dissonance, direct experience, diversity, and social transmission. Three strategies that increase the probability that students will engage in the learning process and attend to the cognitive disequilibrium are also discussed: structure that focuses the students' attention on the disequilibrium, psychological support to help students manage the ego-threatening activities of learning, and "plus-one" instruction designed to tune into the students' level of thinking. It is suggested that some combination of instructional methods under certain conditions can facilitate cognitive growth. (SW)

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Teaching Problem-Solving: Implications from Cognitive Development Research

by Jerry K. Stonewater and Barbara B. Stonewater

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Several months ago we were taking a walk around the block with our two daughters, Jennifer, 8, and Sara, 4. It was a beautiful night, with a full moon, and as we walked, we talked. It occurred to us that an excellent laboratory was at hand and that we could do some experimenting. As we walked around the block, our perspective on that beautiful moon changed. As we headed south, the moon was over our left shoulders; when we turned and headed north, the moon was over our right shoulders. We asked the girls, "Why was the moon over our left shoulders when we started and now it's over our right shoulders? How did it get there?" Sara, the four-year-old, was clearly puzzled. She then looked at us very carefully and said calmly, "They have strings."

A laboratory indeed. Sara very clearly exemplified one of the basic premises of cognitive developmental theory: we construct explanations and solve problems in ways that are consistent with our mental structures and our ways of thinking, regardless of how inappropriate these structures might be. Sara constructed an explanation and a reality different from the one we might use and different from the one that Jennifer might use.

The point of this story applies equally well to college students: unless instruction is somehow "matched" to the student's way of making meaning out of reality, the student will learn little. As we saw with Sara, students translate their experience to be consistent with how they understand. Hence, if we are teaching students to solve high-level, complex problems and they are not yet at this cognitive level, they will either be unable to solve the problem or will provide a solution--however meaningless—consistent with their level of development. Moreover, research has clearly documented that anywhere from 42 to almost 90 percent of our college students are not at levels of cognitive development necessary to do this high-level, abstract problem solving and thinking (Elkind, 1962; Griffiths, 1973; Lawson & Renner, 1974; McKinnon, 1970; McKinnon & Renner, 1971; Stonewater, 1977; Tower & Wheatley, 1971).

One piece of the solution for improving students' problem solving skills rests in the application of cognitive development theories to instruction (Kohlberg, 1969; Perry, 1970; Piaget, 1952). The theories suggest that students' thinking and problem solving abilities are different at each stage and become more complex and sophisticated at each advanced stage, and that learners can think at their stage or below, but not above. Thus, an application of theory to improving problem solving lies in the development of instructional strategies that move students to higher cognitive developmental stages representative of more complex problem solving capabilities.

Instructional Strategies

Instructional strategies that facilitate cognitive development can be categorized into two groups: 1) instruction that challenges the student's cognitive structures or creates disequilibrium, and 2) instruction that provides support such that the student will "engage" in the opportunity created by the disequilibrium. According to Sanford (1966), the student's experience should include a delicate combination of challenges to the student's current level of development and support to move on to the next stage. Piaget

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(1952) describes the creation of disequilibrium as a necessary condition for movement to the next stage. Consequently, instruction that in some way upsets or challenges the student's view of reality and subsequently forces the student to reorganize thought structures, is critical.

The complement to the challenge, however, is the support that allows students to manage the challenges. It is not sufficient to merely provide the disequilibrium. The student must attend to the opportunity and actively engage in confronting, experiencing, and thinking about the disequilibrium-producing opportunity. Thus, creating the opportunity is necessary but not sufficient; using an engagement strategy will increase the probability of cognitive development.

Creating Disequilibrium

There are four types of instructional strategies that have been used successfully to introduce disequilibrium: creating dissonance, direct experience, diversity, and social transmission. These strategies can, and often do, overlap in the actual practice of instruction.

Creating Dissonance—In their course on biology for elementary education majors, Lawson and Snitgen (1982) taught various reasoning patterns, among which were control of and isolation of variables, and proportional, correlational, probabilistic, and combinatorial reasoning. Laboratories were developed for each pattern. For example, student groups were required to study the effects of various sources of energy on germinating seeds. They had to build into their experiment different groups where the amount of light varied, while all other variables (fertilizer, etc.) were held constant. If, for example, one student group appropriately designed the experiment, while another group varied both the light and the other variables, their graphs of growth amount by day could be compared, leading to different results. This discrepancy should create the required dissonance for students.

Results indicated that students made significant cognitive development gains. On a pretest, six students were classified as concrete operational, 26 were in transition to formal operations, and four were formal, while a posttest revealed no students were concrete, eight were in transition, and 24 were formal. Although there were two unaccounted for students in the posttest group, the movement is in the direction of increased formal operational reasoning.

Another strategy for creating dissonance that has been found to be successful primarily in the development of thinking about moral issues is Kohlberg's "plus-one reasoning" (1969, 1975). Kohlberg claims that dissonance is created by discussing moral issues in language reflective of one stage above the students' current level of reasoning. This allows the student to hear higher, more complex reasoning and creates a dissonance with the current reasoning, encouraging movement to the next stage. However, discussion more than one stage above a student's current level of thinking will not be heard. For example, students are presented with carefully prepared open-ended moral dilemmas and then engage in discussions about these dilemmas. Classes are structured such that students are exposed to moral reasoning one stage above their own, thus creating conflict and dissonance. Though most of the research in moral discussion is with high school students or below, the evidence is mounting that students exposed to the moral discussion/plus-one process do evidence significantly greater cognitive moral growth than those under control conditions (Beck, Sullivan, & Taylor, 1972; Blatt & Kohlberg, 1973; Colby, Kohlberg, Fenton, Speicher-Dubin and Lieberman, 1977; Harris, 1977).

Direct Experience—Carefully planned direct experience activities can be another method to create disequilibrium in students. This involves activities that give them some kind of hands-on experience with the content.

Widick & Simpson (1978) describe a history course designed to examine direct experience and other instructional variables and their relationship to content learning and cognitive development. In the experimental section, an example of direct experience was used by the instructor to dispell stereotypic notions about the Great Depression. Students were asked to interview people who had lived through the Depression—a black cook who had lived in the South, a physician's wife who had lived in a well-to-do suburb, and an immigrant. After the interviews, students were to write a report and address questions concerning similarities and differences among those interviewed. This "hands-on" experience with different kinds of people can create disequilibrium and teach students about multiple perspectives. Results indicated that both cognitive stage movement and content mastery was greater in the experimental history course than in two comparison courses. Content mastery was measured by performance on the final exam; the experimental group's scores were significantly higher than the comparison groups' scores. However, cognitive stage movement was less clear cut. While the experimental section had the greatest percentage of students showing stage movement (63%), students in the two comparison groups also showed positive stage movement (57% and 40%).

Another study of the use of direct experience in mathematics was conducted by Buerk (1981, 1982). Her subjects were a group of women who were generally advanced cognitively (relativists on the Perry scheme) but who tended to view mathematics in very simplistic, dualistic terms. Buerk used direct experience through a small group structure in which the women experienced a mathematically-oriented problem. An example problem is the belted earth puzzle: Place a steel belt around the earth at the equator so that it fits snuggly. Now add 40 feet to its length. Determine the distance between the earth and the belt. (The answer, by the way, is 6-plus feet). Results of the five different small group sessions indicated that each woman changed significantly in the direction of relativistic thinking about mathematics and exhibited a reduction in general math anxiety/avoidance.

Diversity—One of the reasons students do not move out of the lower cognitive stages and tend to approach problem solving in a unidimensional fashion is that they see the world in what might be described as linear, singular, and non-complex ways. An approach to

break up this singularity of view is to insure that students experience many different perspectives and viewpoints so that their understanding of the world becomes more multiplistic and complex. Presenting students with a diversity of experiences is one way to do this in the classroom.

Diversity is seen as multiple avenues to the "truth," multiple perspectives on a phenomena, or multiple activities; each brings a slightly different "bent" on reality. Knefelkamp (1974) and Widick (1975) describe this criterion as a component of their developmental instruction model to facilitate cognitive development according to the Perry (1970) scheme.

In the history course that Widick and Simpson (1978) described, a role playing activity was used to help students think more complexly about Prohibition. Students were given the Prohibition legislation that was actually presented to the Ohio legislature and were assigned roles as people who were living at the time. Then they were asked to present coherent, substantial arguments for their positions. The various presentations were sequenced to insure that conflicting and divergent positions were heard. The instructor explicitly challenged and questioned each group to consider alternative explanations to their own positions. By so doing, the students had the opportunity to experience each different perspective. The diversity helped to create the disequilibrium necessary to stimulate cognitive development.

Social transmission—Piaget (1952) specified that one of the conditions necessary for cognitive development was social interaction with others. Traditionally, instruction using this device focuses on classroom interaction among peers after some sort of an experience that created cognitive dissonance.

Ward and Herron (1980) describe using social transmission in a study comparing traditional chemistry lectures with an experimental section based on the learning cycle approach. Experimental section students conducted an experiment without previous instruction on the embedded concepts. During class discussion, they generated inferences and hypotheses from the experiment and discussed their ideas with other students in the lab. Students were given an opportunity to discuss and generate trial hypotheses and confront other students' trial hypotheses in a setting reminiscent of late night dormitory "bull" sessions. Thus, the social transmission of "my" hypothesis vs. "your" hypothesis set the stage for a variety of ideas, viewpoints, and reasons.

The authors assessed the extent to which the instructional treatment effected content mastery and found that formal operational students outperformed the concrete students on test questions that required either concrete or formal reasoning. Disappointingly, in only one of three experiments did the use of social transmission significantly improve the concrete operational students' performance on the test questions. Despite these results, the authors did report an interesting relationship between course grade and level of intellectual development. While none of the concrete students received a grade above "B" and 74% of them received "D's" or "F's," only 25% of the formal operational students received "D's" or "F's."

Though the evidence for social transmission as a strategy to help bring about cognitive disequilibrium is less convincing than that for other strategies, it becomes evident that interaction among students can be a useful tool. Perhaps the difficulty lies not with social transmission as a strategy, but in trying to isolate it from other disequilibrium-creating methods.

Engagement

One of the most critical aspects of successful instructional intervention studies is developing methods that increase the probability that students will engage in the learning process and attend to the particular cognitive disequilibrium that is being created. Three strategies will be discussed: structure that focuses students' attention on the disequilibrium, psychological support to help students manage the ego-threatening activities of learning, and "plus-one" instruction designed to tune-in to the students' levels of thinking.

Structure—Structure can be defined as those elements of instruction that establish boundaries and organize the content in such a way that helps make the disequilibrium manageable.

Widick & Simpson's (1978) U.S. history course is a good example of how structure was used to increase the probability that students would attend to the conflicting information obtained in their interviews. Students were asked to write about their interviews and specify similarities and differences between interviewees. The writing requirement forced the students to discriminate between people. It also gave the students a structure through which to think about and engage in what they had experienced.

In the other studies designed to examine the Knefelkamp (1974) and Widick (1975) developmental instruction model, structure appears as a key support element for cognitive growth in dualistic students. Widick & Simpson (1978) include a high degree of structure including specific assignments, clear expectations, and a good deal of involvement with the professor, which they feel enables students to attend to diversity and dissonance. They feel that "dualistic students seem to need specified and externally directed learning activities and only a few demands for self-direction." (p. 34)

Psychological support—Creating disequilibrium and leading students to attend to it in order to change how they think about the world can be a very ego-threatening and anxiety-producing activity. Thus, methods to help the student manage the anxiety are useful.

Numerous authors believe that creating a personal environment in the classroom is a way to do this. Simple things like knowing students' names, listening attentively, responding to students in supportive ways, and making personal and meaningful comments on their papers are ways of personalizing the environment. (Knefelkamp, 1974; Widick, 1975)

A good example of psychological support is found in the moral discussion literature. Harris (1977) attempted to determine if providing psychological support before using the moral discussion approach would result in greater gains in moral judgment scores. Using Mosher and Sprinthall's (1971) deliberate psychological education approach, one experi-

mental group was exposed to nine weeks of experiences such as trust building, role taking and empathy, and basic communications skills, followed by nine weeks of moral discussion using planned moral dilemmas. A second group had 18 weeks of moral discussion. The third group was not exposed to either. While both experimental groups exhibited about the same change on Moral Judgment Interview scores (Kohlberg, Colby, Speicher-Burbin, Lieberman, 1973), the group with the combination approach showed all of its change during the last nine weeks. It is possible that the nine weeks of psychological support may have set the stage such that a group could then experience the same growth in nine weeks as the other group experienced in 18 weeks.

Though the work using psychological support is inconclusive, the evidence indicates that it may have potential as an enabling strategy.

Kohlberg Plus-One—A few brief comments are in order about "plus-one" as an engagement strategy. Evidence was cited earlier describing this as a method of creating dissonance. However, discussion (and instruction) that is one level above a student's current level of reasoning may provide the situation that allows the student to hear the dissonance that is created. That which is too far above the students' reasoning ability will not be understood.

Summary

The relationship between cognitive development and problem solving skills has been documented. It is clear that, at higher levels of cognitive development, students are able to conceptualize their world and perform tasks that, at least in part, aid in their problem solving ability. The relationship of the instructional strategies described, however, is not as clear. Often these instructional strategies are used in combination and, in fact, none of the strategies have been studied individually. Consequently, results cannot be attributed to single strategies. In addition, these various strategies do not fit into just one arbitrarily defined category; rather, they overlap categories. For example, the Depression exercise in the Widick and Simpson (1978) history course was designed to provide direct experience. At the same time, however, the experience created dissonance for the students as well as exposure to diversity, all of which led to cognitive disequilibrium.

What can be learned from the cognitive development research? There seems to be some combination of methods which, when used under certain conditions can, in fact, facilitate cognitive growth. It would be appropriate to continue such research with an emphasis on isolating the different strategies. However, it would be equally important to further analyze these strategies, combined with student assessment and classroom environment data, to develop a workable and transferrable model of engaging students in disequilibrium-creating activities. ■

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